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SPREAD-SPECTRUM RADIO SYSTEMS AND NETWORKS

FINAL REPORT

submitted by

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October 25, 1993

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This is the final report for the research program titled *Spread-Spectrum Radio Systems and Networks* which was supported by the U. S. Army Research Office under Grant DAAL03–91–G–0154 (Proposal Number 27994-EL) for the period May 21, 1991 – July 20, 1993. The research was carried out at the University of Illinois at Urbana-Champaign under the direction of Professors Michael B. Pursley and Dilip V. Sarwate who were the principal investigators for the contract.

As part of the research completed under the subject contract, we showed that the effectiveness of error-control coding in a frequency-hop radio system can be in creased greatly by the use of side information developed in the radio receiver. For slow-frequency-hop transmission, the inclusion of test symbols in each dwel l interval provides a simple method for the derivation of side information for that dwell interval. Requirements on the reliability of the side information are presented in [9] and [14], and their implications in determining the necessary number of test symbols per dwell interval are described.

When applied to a frequency-hop radio, concatenated coding provides a method for simultaneously achieving a larger communication range and greater protection ag ainst partial-band interference than can be obtained by systems without error-control coding or even most systems with a single form of coding. We have examined various forms of concatenated coding with different types of interleaving in [8], [10], [13], and [20]. For all approaches that we have considered, Reed-Solomon (RS) codes are employed as the outer codes. The decoders for the inner codes provide side information for use in decoding the outer RS code, so that it is not necessary to transmit separate test symbols. In [8] and [20], side information is derived from the inner decoder, and test symbols are not employed. Some comp arisons between concatenated coding methods that employ test symbols and those that do not are given in [13].

Hard-decision and soft-decision decoding methods are applied to both block and convolutional inner codes in [20], where we show that simple block codes are very effective as inner codes. Soft-decision decoding is emphasized in [10], and the relative advantages of two alternative interleaving methods are presented in [13] . In one alternative, the convolutional inner code is used as a block code within each dwell interval, while in the other, the convolutional inner code is also interleaved across the dwell intervals. More recently, we have investigated the use of short nonlinear block codes as inner codes, and we have found that these give excellent performance when applied to frequency-hop radio transmission in the presence of partial-band interference.

Research has also been completed on combined decoding and equalization for trellis codes used on channels with intersymbol interference. We have devised iterative methods for computing upper bounds on the probability of error for maximum-likelihood sequence estimation and shown that this method also can be applied to reduced-state sequence estimation. The latter estimation technique is of interest because it reduces receiver complexity. We have also studied a combination of minimum-mean-square error and decision-feedback equalization for radio channels. Performance results based on bounds and simulations are given in [5] and [15] respectively.

A direct-sequence spread-spectrum communication scheme using continuous-phase-modulation (CPM) has been studied in [4]. We have also devised efficient methods for computation of the power spectral density of such spectrum signals [6] as well as for general M–ary LREC signals [19]. We had hoped to be able to find simple relationships between the properties of the signature sequence and the resulting power spectral density. However, the sequence affects the power spectral density in very complicated ways and it seems unlikely that any simple relationship or even a heuristic rule of thumb can be found. CPM signaling effectively introduces memory into the channel, and this can be exploited by a receiver to achieve better performance than (say) phase-shift-keyed signaling. This holds true even for the direct-sequence CPM scheme and receivers that can achieve such performance are discussed in [4]. Unfortunately, the receivers are very much more complicated than the receivers for phase-shift-keyed direct-sequence signals, and it appears that error-control coding is likely to be a more cost-effective way of achieving the same performance.

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*1.   U. Madhow and M. B. Pursley, "A parallel systems approach to universal receivers," *IEEE Transactions on Information Theory*, vol. 37, pp. 291–306, March 1991.

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